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Symmetry Breaking Bifurcations and the Growth of Chaos in a Rotating Fluid

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Harry L. Swinney

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Laboratory experiments and numerical simulations on flow between concentric independently rotating cylinders (the Couette-Taylor system) reveal a primary bifurcation to a new state ribbons, which are traveling waves in the azimuthal direction but standing waves in the axial direction. Other experiments, conducted on a rigid rapidly rotating annulus, are designed to explore parameter regimes characteristic of planetary scale flows. Eastward jets are found to exhibit Rossby waves for a wide range of control parameters, and these jets (or, more precisely, the potential vorticity gradients in the core of the jets) act as a strong barrier to tracer transport; these observations have important implications for the transport of pollutants in oceans and the atmosphere. The behavior of westward jets is found to be markedly different from that of eastward jets: persistent vortices (like the Great Red Spot of Jupiter) are found to form spontaneously in a turbulent shear flow formed by westward jets.

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22a NAME OF RESPONSIBLE INDIVIDUAL
Harry L. Swinney

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NAME OF PRINCIPAL INVESTIGATOR: Harry L. Swinney

NAME OF ORGANIZATION: The University of Texas at Austin

ADDRESS OF ORGANIZATION: Physics Department, Austin, TX 78712

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PAPERS SUBMITTED TO REFEREED JOURNALS
(Not yet published)

"Nonlinear standing waves in Couette-Taylor flow," R. Tagg, S. Edwards, H. L. Swinney, and P. S. Marcus, submitted to Phys. Rev. Lett. (1988).

"Laboratory model of a planetary eastward jet," J. Sommeria, S.D. Meyers, and H.L. Swinney, Nature, to appear.

"Divergence-free velocity fields in nonperiodic geometrics," L. Tuckerman, to appear in J. Computational Physics.

"Transformations of matrices into banded form", L. Tuckerman, to appear in J. Computational Physics.

"Steady-state solving via Stokes preconditioning: recursion relations for elliptic operators," L. S. Tuckerman, to appear in *Proc. of the Eleventh Int'l. Conference on Numerical Methods in Fluid Dynamics*, ed. by D. L. Dwoyer, M. Y. Hussaini, and R. G. Voigt (Springer-Verlag, Berlin, 1989).

"Traveling waves in axisymmetric convection: the role of sidewall conductivity," D. Barkley and L. S. Tuckerman, submitted to *Physica D* (1988).

PAPERS PUBLISHED IN REFEREED JOURNALS

"Primary instabilities and bicriticality in flow between counterrotating cylinders," W.F. Langford, M. Golubitsky, R. Tagg, E. Kostelich, and H.L. Swinney, Phys. Fluids **31**, 776-785 (1988).

"Instabilities and chaos in rotating fluids," in *Nonlinear Evolution and Chaotic Phenomena*, ed. by G. Gallavotti and P. W. Zweifel (Plenum Publishing Co., 1988), p. 319-326.

"A laboratory simulation of the great red spot of Jupiter," J. Sommeria, S.D. Meyers, and H.L. Swinney, Nature **331**, 689-693 (1988).

"Numerical simulation of Jupiter's Great Red Spot," P.S. Marcus, Nature **331**, 693-696 (1988).

"Global bifurcation to traveling waves in axisymmetric convection," L. S. Tuckerman and D. Barkley, Phys. Rev. Lett. **61**, 408-411 (1988).

PAPERS PUBLISHED IN NON-REFEREED JOURNALS

None

TECHNICAL REPORTS PUBLISHED

None

BOOKS (AND SECTIONS THEREOF) SUBMITTED FOR PUBLICATION

None

BOOKS (AND SECTIONS THEREOF) PUBLISHED

None

PATENTS FILED

None

PATENTS GRANTED

None

INVITED PRESENTATIONS BY H.L. SWINNEY AT TOPICAL OR SCIENTIFIC/TECHNICAL SOCIETY CONFERENCES

10/2/87	Schlumberger (Austin), Seminar
10/9/-10/87	J. H. Taylor Symposium, Rhodes College, Memphis
10/21-23/87	Dynamic Patterns in Complex Systems, Bahia Mar, Florida
12/14/-15/87	Ed Lorenz Symposium, M.I.T.
2/24/88	Duke University, Physics Department Colloquium
4/13/88	Chaos Review Panel, Jason, Scripps Institute of Oceanography
4/20/88	American Physical Society Annual Meeting, Washington, D. C.
4/21/88	Clarkson University , Physics Colloquium
5/4-5/88	Department of Energy Symposium on Energy Engineering Sciences, Argonne
5/12/88	Rutgers Statistical Mechanics Meeting, Newark, NJ
5/16-20/88	Advances in Fluid Turbulence, Los Alamos, New Mexico
7/26-8/5/88	Enrico Fermi International School of Physics, Nonlinear Topics in Ocean Physics, Varenna, Italy (3 lecture course)
7/29/88	National Institute of Optics, Florence, Italy, Seminar
9/15/88	Texas A&M University, Physics Colloquium
9/21-22/88	Chemical Engineering Colloquium, Rice University, Houston, TX

CONTRIBUTED PRESENTATIONS AT TOPICAL OR SCIENTIFIC/TECHNICAL SOCIETY CONFERENCES

11/23-25/87	"Stability of Flow Between Counter-Rotating Cylinders", Randall Tagg, Eric J. Kostelich, and Harry L. Swinney, Annual Meeting of the American Physical Society, Division of Fluid Dynamics

OTHER RECENT PROFESSIONAL ACTIVITIES
(H. L. Swinney.)

Director, The Center for Nonlinear Dynamics, University of Texas, 1985-
Editor, Physica D-Nonlinear Dynamics (North-Holland Publishing Co., Amsterdam), 1982-1986
Member of the Executive Committee, Division of Fluid Dynamics, American Physical Society, 1983-86
Co-organizer, Fluid and Plasma Turbulence Conference, Austin, Dec. 7-11, 1987
Co-organizer, Dynamics Days Texas, Houston, January 5-8, 1988
Member of the Organizing Committee, Complex Systems Summer School, Santa Fe, June 13-July 18, 1988
Organizer of course entitled *CHAOS* — 7 lectures of 3 hours each held on 7 successive Fridays at The University of Texas Applied Research Laboratory, March 25-May 6, 1988
Organizing Committee, Year of Dynamics (1989-90), Institute of Mathematical Analysis, University of Minnesota
Member, Advisory Board for the Warwick Nonlineqar Systems Laboratory, 1986-
Member, Science Board of the Santa Fe Institute, 1987-
Member, External Advisory Board, Center for Interdisciplinary Complex Systems, University of Arizona, 1987-

GRADUATE STUDENTS SUPPORTED UNDER CONTRACT FOR YEAR ENDING 30 SEPTEMBER 1988

Bright Dornblaser
William S. Edwards
Andrew Fraser
John Good
Steve Meyers
Michael Schatz

POSTDOCTORALS SUPPORTED UNDER CONTRACT FOR YEAR ENDING 30 SEPTEMBER 1988

Eric Kostelich
Randall Tagg
Laurette Tuckerman